BEDROCK DENUDATION ON TITAN: ESTIMATES OF VERTICAL EXTENT AND LATERAL DEBRIS DISPERSION. J. M. Moore[1] A. D. Howard[2], and P. M. Schenk[3], [1]NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035 (jeff.moore@nasa.gov), [2]Dept. of Environmental Sci., University of Virginia, Charlottesville, VA 22903 (ah6p@virginia.edu), [3]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058 (schenk@lpi.usra.edu).

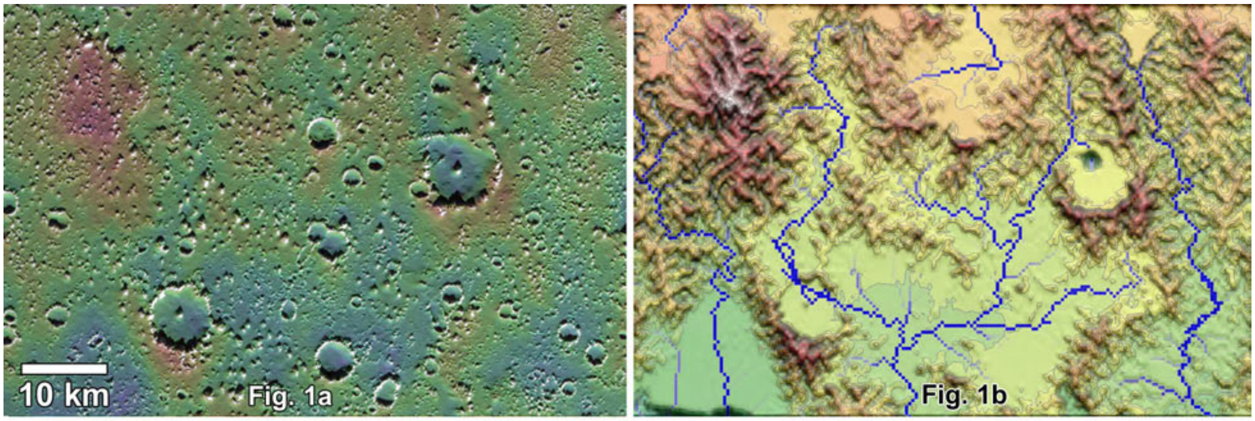
Introduction: Methane rainfall and runoff, along with aeolian activity, have dominated the sculpting of Titan's landscape. A knowledge of the vertical extent of bedrock erosion and the lateral extent of the resulting sediment is useful for several purposes [1]. For instance, what is the magnitude and expression of modification of constructional landforms (e.g., mountains)? Does highland denudation and the filling of basins with sediment cause adjustments (uplift and subsidence) in the crustal ice shell? Here we report preliminary findings of putative eroded craters and the results of landform evolution modeling (Fig. 1) that suggest that ~ 250 m of net bedrock erosion has at least locally taken place and ~1 km of maximum local erosion.

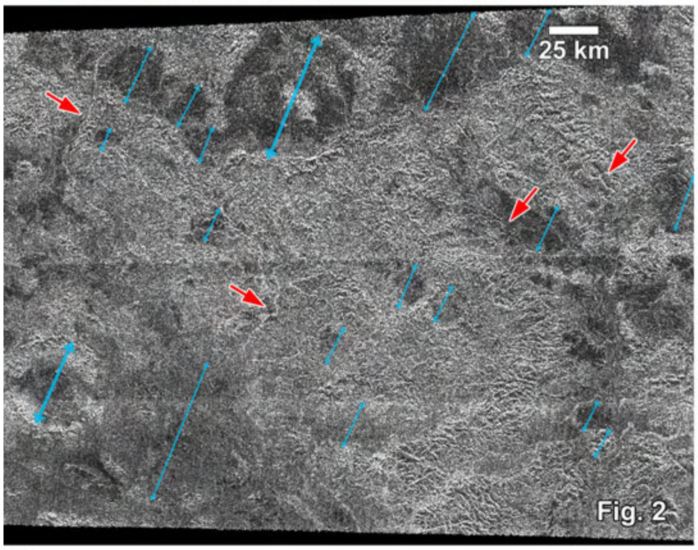
Observations: We have identified several examples of putative cratered terrain. These are regions containing an obvious concentration of circular features that may be radar bright or radar dark (Figs. 2 & 3). In some cases (Fig. 2) some of these features are obviously degraded impact craters. We provisionally interpret less definitive circular features to be highly-degraded impact craters as well. These putative craters typically range in diameter ~ 20 – 50 km.

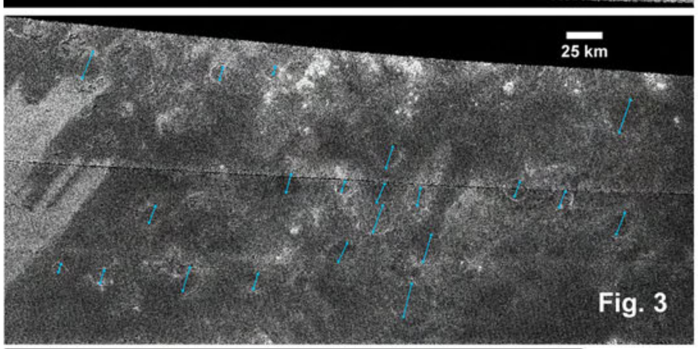
Crater rim heights (relative to their external surroundings have been measured on similarly sized icy Galilean satellites, Ganymede and Callisto [2]. Depending whether the rim heights are related to central pit craters or central peak craters, the rim heights range between ~250 - 350 m for the former and ~350 - 800 m for the later. Central peak craters appear to be the case, where determinable, on Titan [3]. We make the simple argument that the loss of craters smaller than ~ 20 km in diameter and the underabundance and extreme degradation of many of the larger putative craters suggest that vertical erosion has, in the limit, removed the rims of some craters, indicating at least ~250 m of erosion, with reasonable values being perhaps as high as ~800 m.

Simulation Modeling: We use a landform evolution model (LEM) [4] to simulate fluvial and lacustrine modification of a cratered landscape on Callisto (Fig. 1) to evaluate the amount of fluvial erosion necessary to replicate the present Titan cratered terrains (Figs. 2 & 3). We used high quality Digital Elevation Models (DEMs) generated from imaging of Callisto [e.g., 5]. For this work we assumed complete runoff, so that depressions become lakes, and drainage exits somewhere along edges of the simulation domain. Edges of simulation domain were fixed (non-erodible). Flow rates were scaled to Titan gravity. Rate of channel incision was set to be proportional to shear stress on bed. Weathering in the model produced transportable debris. Sediment was deposited in low-lying areas. In LEMs the spatial pattern of erosion does not vary much with different parameters but the rate of erosion is very affected. For the purposes of these initial trials, the *pattern* not the rate, was deemed most important. Fig. 1a shows a topographic model of the Asgard region of Callisto that we assume for the initial conditions for the simulation. Fig. 1b shows the simulated erosion after 150,000 model years, with an overprint of the main drainage paths in blue. Most of the craters less than 5 km in diameter have been so modified as to be unrecognizable. Fluvial erosion and deposition may delineate degraded impact basins, such as at the top of Fig. 1b. Crater rims and uplands have become intricately dissected by fluvial erosion. The simulation was continued until about 750,000 model years with continued diminishment of relief and increased size and areal coverage of low-relief sedimentary basins. Fig. 4 shows the decrease in mean surface elevation by transport of sediment through the simulation domain boundaries. A total of about 250 m of net erosion occurred during the simulation, with the greatest local erosion of about 950 m. The black arrow shows the total relief reduction at the time shown in Fig. 1b.

Discussion: Our preliminary conclusion is that ~ 1 km of vertical erosion from fluvial action has taken place at least locally, with regional average erosion of 100s of meters being possible. There is good evidence that much of this sediment is transported distances in the 100 km range into local basins, such as can be seen in Fig. 2. More difficult to easily ascertain is whether material eroded from large regions, such as Xanadu, has been efficiently transported globally, or at least on large enough scales, to affect the state of isostacy. Several studies have suggested that there may have been transportation on this scale with attendant effects on isostacy or the lack there of [6, 7]. This is a subject of our ongoing investigation. We are also investigating methods of characterizing the total amount of fluvial erosion by characterizing the relief properties of eroded landscapes [1].







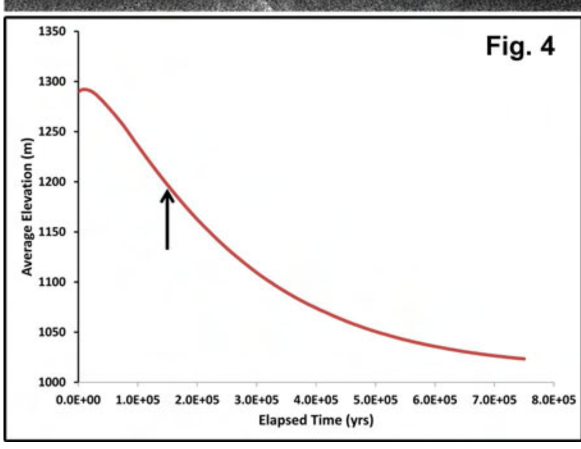


Fig. 1. (a) A portion of the Asgard region on Callisto colo-ried by a DEM of this region [5]. Callisto's cratered sur-face, which is mantled (but so is Titan's by atmospherically derived solids) and only weakly tectonized (i.e., basin ring graben). **(b)** This same DEM operated upon using our Landform Evolution Model (LEM) to show the effects of flu-vial erosion, transportation and deposition. When rained upon produces a surface where the highlands are fluvially dissected and the lowlands are broadly filled with sedi-ment. This resembles much of the highlands of Titan (see Figs 2 and 3). This landscape roughly shows the same size range and preservation state of degraded craters as seen in Figs 2 & 3. Figure 4 shows the amount of erosion reqired to grenerate this landscape.

Fig. 2. This region is interpreted to consist of radar-bright fluvially dissected uplands with darker lowlands containing fine-grained alluvial sediment. Red arrows point to ex-amples of bright-floored fluvial valleys. This region also exhibits a considerable number of possible degraded cra-ters. Two of these (marked by thick blue arrows) are read-ily identified as craters. Thin blue arrows identify a number of circular structures that may be strongly degraded cra-ters. Portion of swath T13, ~10°S, 83°W

Fig. 3. A broad generally radar dark region exhibiting nu-merous possible degraded craters (blue arrows). We ge-nerically refer to this as *putative cratered terrain*. Thin blue arrows identify a number of circular structures that may be strongly degraded craters. Portion of T43, ~25°N, 170°W

Fig 4. Plot of mean elevation change over 750,000 mod-eled years. The black arrow shows the net amount of ero-sion at the time shown in Fig. 1b (150,000 years). Because the lateral boundaries are fixed, mean elevation change represents sediment transported out of the lateral bound-aries. In a broader planetary context the total erosion in a local region would depend on the relief characteristics of the surrounding terrain. So that, if the local region were to-pographically low, import of sediment from the surround-ings might overwhelm local erosion. On the other hand, if the local region were elevated, fluvial erosion of the lateral boundaries (assumed fixed in the simulation) might in-crease the net total erosion. The correspondence of simu-lation years to actual years of erosion on Titan would depend upon the intensity and duration of precipitation events as well as bedrock erodibility.

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